

*Comparison  
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BODY SCANNERField of the Invention

The invention relates to body scanners.

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Background

The invention relates more particularly to photographic body scanners that are capable of forming images or records of a body for use in making up suitable garments. Such records may be used in other fields such as surgery or pathology where 3-dimensional information is required. Although various imaging techniques are known using laser sources and mechanical plotting of images, the present invention is directed to scanners that incorporate projection moiré topography where we have now been found it possible to create scanner systems that are physically compact, relatively low in cost, and require a short scanning distance.

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Although various non-contact imaging techniques are known which use a laser or infrared light source, they require time to move the sensors to scan a human body, which also affects the data accuracy. Laser strobe or invisible light spectrum radiation may also cause harm to human eyes and organs.

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Summary of the Invention

It is an object of the invention to overcome or at least reduce these problems.

5 According to the invention there is provided a compact moiré effect body scanner for generating 3-D images, the scanner including an elongate projection module having a light source, a first objection lens for directing a beam of light from the source along a first central  
10 longitudinal axis, a first photographic grid for the beam of light and mounted in a plane at right angles to the first central axis to allow light to illuminate a body to be scanned, and an elongate imaging module adjacent the projection module having a second central  
15 longitudinal axis parallel to the first central axis, the imaging module incorporating a second objective lens for receiving reflected from the body, a second photograph grid for the reflected light and mounted in a plane at right angles to the second central axis, and an  
20 imaging means for recording the reflected deformed grating from the body captured beyond the second photographic grid.

The imaging means is preferably a digital camera.

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The first and second objective lenses preferably have the same focal length and are mounted in a same common

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plane.

Nodal points of the two objective lenses preferably are separated by the same distance from the respective photographic grids.

#### Brief Description of Drawings

A compact moiré effect body scanner according to the invention will ~~set~~now be described by way —or example with reference to the accompanying drawings in which:-

Figures 1A, 1B, and 1C are moiré contour pattern images of a front, side and rear view of a human torso;

Figure 2 is a schematic view of a set-up of the scanner to images of a human body;

Figure 3 shows typical high density parallel equal spatial gratings for use in the scanner, and

Figure 4 is a schematic layout showing components of the scanner.

#### Detailed Description

Embodiments of the invention comprise a compact design of photographic 3D scanners that are capable of forming accurate moiré topographic images from a human body

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surface at short distance, in a short duration, and that  
are light-weight, and low-cost for use in making perfect  
fit garments. Such records may be used in other fields,  
such as surgery or pathology where three-dimensional  
5 information is required.

The embodiments of the present invention comprise  
scanners that modify a technique of projection moiré  
topography. The basic technique uses optical  
10 interference that occurs ~~by~~ from two identical high-  
density gratings. When the reference grating is  
projected onto the surface of human body ~~by~~ with an  
objective lens, its varying dimension will deform the  
grid line shadow. This deformed style of grating is  
15 then reflected and captured by another identical  
objective lens simultaneously. When the deformed  
reference grating passes through the parallel detection  
grating, the relative displacements of one grating with  
respect to the other is provided. (see Figures 1A, 1B  
20 and 1C)

It is, however, possible for embodiments of the present  
invention to operate under normal light conditions.  
High-speed pulse light ~~with~~ in the visible spectrum is  
25 used as a safe light source. The scanner system can  
capture 3D human body images from a short distance, up  
to 0.8 meters (see Figure 2~~+~~), quickly, within 1/1500

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second. The scanner is physically compact, light weight and relatively low in cost. Such a design, of a high speed and high quality moiré compact scanner, fulfills the contemporary market requirement. Short focal length objective lenses are used to cover a wider projection area of ~~the~~ a field up to 1109.94mm vertical and 924.95mm horizontal at a 1200mm distance. The coverage at 800mm distance is 721.74mm vertical and 601.45mm horizontal.

A high density parallel grating (see Figure 3) is made by using Kodak type #160-01 special glass plate, in order to avoid optical aberration and high light-diffraction factor due to the wide angle of light rays and adjacency of a rear nodal point. Since a light sensitive emulsion layer is less than 5 microns thick, it decreases the optical diffraction rate and increases the resolution and contrast of the moiré contour; this improves sharpness around edges of images. The emulsion is coated on a quality soda lime type optical flat glass base. It is therefore a highly transparent optical glass exhibiting stable ~~dimensions~~ dimensions having only 1.5mm thickness. This will increase image quality and ensure data accuracy. To prevent noise resulting from a high fog level index of photographic silver bromide emulsion, a modified photographic film-developing chemical is also applied to achieve a high contrast

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range of 2.90 at Light Opacity Log  $E_e$ , which produces low fog level and increases the resolution. Multi-coating is used on each air-glass surface with a thickness of  $1/4$  wavelength of the incident light wave within the visible spectrum. This increases the light transmission and reduces reflection.

A flash unit is used to produce 1600 watt seconds of pulse light in the visible spectrum at 400 to 700 nm as a projection light source. Although the light intensity is powerful, it will not incur any harm to the human body. The image capturing duration takes less than  $1/1500$  second and so minimizes any adverse effects that would normally be caused by body movement. A piece of UV heat absorption glass and low pass filter is applied to cut off long wave infrared and to control the light wavelength to within 400 to 700 nm. This is used not only to maintain a higher safety factor, but also reduces chromatic aberration due to the light dispersion of optical glass when a wide range of light wavelength passes through the optics. Another purpose of this heat absorption glass is to prevent changes in the dimension and density of the glass plates, especially for the projection grid.

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The design of image optical system that transfers the ~~unparalleled light ray~~ non-parallel light rays of

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contour images into the objective lens requires special  
mention. This is called the "field lens" (optical  
transfer component) which has an aspherical curved  
surface to correct some optical aberration such as  
5 spherical aberration, barrel or pincushion distortion  
and field curvature which is caused by the objective  
lens. The light rays are collected by a group of  
Fresnel lenses so as to condense the light passing  
through the photographic grid plane. High-density  
10 parallel reference gratings with ~~equal space of equally~~  
spaced lines and gaps are projected onto a human body by  
the objective lens. The lens aperture is predetermined  
to produce sufficient depth-of-field to cover a required  
part of the human body. The reflecting grating image  
15 from the body is deformed due to its varying dimensions  
and is simultaneously captured by the other objective  
lens. The gratings have the same lens aperture for  
obtaining identical depth-of-field, depth-of focus and  
image magnification as the projection system. The  
20 ~~images of deformed grating pass~~image passes through the  
detection grid that is located at the focal plane of the  
image capture objective lens. The optical interference  
occurs and forms a moiré contour map.

25 Since the angle of light rays of the contour map from  
two objective ~~lens~~lenses are not in a parallel point  
source condition, the scanner cannot capture the full

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frame image by using the other objective lens of a digital camera. A group of optical transfer system field lenses would be required in between the detection grid and the objective lens of the digital camera. One  
5 surface of the field lens is a-spherically designed to balance the spherical aberration and the curvature of field caused by the objective lens, and one surface of the field lens is plano-convex. The function of field lens group is to capture the light rays and refract them  
10 as a parallel point source which is well suited to form the full frame image by an objective lens. Finally, the contour image is formed and recorded by the digital camera within a short duration of time. A digitized bitstream signal of contour data is provided for image  
15 analyses and generation of 3-dimensional data of the human body.

Thus, in the embodiment, the scanner comprises two objective lenses, with athe same focal length and  
20 optical design, located in parallel in the same common plane. Nodal points of the two lenses are at the same distance from the respective grid planes. Two ~~pieces of~~ high-density grid planes have equalequally spaced identical black and white photographic glass gratings of  
25 a density of 17 line pairs per mm for capturing images from a distance of 800 mm. The two grid planes are placed in parallel behind the objective lenses. One

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grid or grating is for light projection and the other is for image detection.

Referring to Figure 4, the layout of the scanner shows  
5 an objective lens 1 for high-density parallel black and white line grid projection towards the human body. An objective lens is arranged to receive the deformed grating image reflected from the human body. An optical transfer system 3, 4 changes the light rays from a non-  
10 parallel to a parallel form, which is suitable for another objective lens to capture whole images and reform the images onto a charge-coupled device. The optical transfer system includes two field lenses 3 and 4. The lens 3 is a plano-convex lens made of optical  
15 glass with an optical multi-coating (radius = 77.52mm). The lens 4 is a double-convex lens made of PMMA highly transparent optical plastic material; one side of the lens is spherical and the other side is aspherical (respective radius 167.2764mm and 35.21515). Two grid  
20 planes 5 are formed of soda lime optical planar glass providing high density black and white grids of high resolution and high contrast and formed with ultra thin chromium emulsion. Both sides of the grid planes are multi-coated.

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A double-convex glass condenser 6 has one spherical side and one aspherical side with a an optical filter 7 and 8

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at each side. The filters 7 and 8 are used for  
absorbing heat and removing ultra-violet light,  
respectively. The filters increase resolution of the  
line grid when it is projected onto the surface of the  
5 target and prevent heat energy from changing the  
dimensions of the glass grid. A planar optical  
diffusion glass 9 diffuses projected light to prevent  
hot-spot imaging of a flash tube onto the human body  
which can be caused by a greater depth of focus when the  
10 objective lens works with a small aperture. A honeycomb  
metal screen 10, with 50% light opacity at its central  
region and 5% opacity at its edges, balances out an  
optical vignette caused by the short focal length  
objective lens 2. The screen produces a more even  
15 illumination of the whole image.

A digital camera 11 has an objective lens 12, which can  
form a maximum of 1:2 close distance, and a high speed  
1/500 second focal plane shutter 13 is used to cut off  
20 ambient light. A CCD light sensor 14 is built in at the  
focal plane of the camera. Analogue to digital encoders  
and generator 15 supply signals to a personal computer  
(PC).

25 A flash unit includes a cooling fan 16 and a U-shaped  
flash tube 17. The flash tube has a UV coating which  
can endure 3200-watt power energy and produce 5600°K

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spectrum light pulses. A flash intensity of 1600 joules produces sufficient light projection with a flash duration of 1/1666 seconds. An optical reflector 18, made of aluminium, collects and diffuses flash light  
5 from a 260 degree angle and reflects the flash light to 100 degree front directional. A ceramic lamp base 19 holds the flash tube 17 and is arranged to receive a power supply via a transformer 20 from DC capacitors 21, 22. There are sixteen capacitors 21 rated at 360V and  
10 1500 microfarads each, and eight capacitors 22 rated at 400 volts and 100 microfarads each. A rectifier circuit 23, limiting resistor 24 and flash trigger circuits 25 complete a power supply circuit for the flash unit. The flash unit is arranged to selectively produce three  
15 levels of intensity of light, namely 400, 800 and 1600 watt seconds.

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4. ~~The lens 3 is a plane convex lens made of optical glass with an optical multi coating (radius = 77.52mm). The lens 4 is a double convex lens made of PMMA highly transparent optical plastic material, one side of the lens is spherical and the other side is aspherical (respective radius 167.2764mm and 35.21515). Two grid planes 5 are formed of soda line optical planar glass providing high density black and white grids of high resolution and high contrast and formed with ultra thin chromium emulsion. Both sides of the grid planes are multi-coated.~~

Figure 4 also shows a flash synchronisation cable 26, a second cooling fan 27, and a cable 28 for delivering bit stream data signals from the analogue to digital converters 15 to the PC.

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5 ~~objective lens works with a small aperture. A honey  
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25 holds the flash tube 17 which and is arranged to receive  
a power supply via a transformer 20 from DC capacitors  
21, 22. There are sixteen capacitors 21 rated at 360V~~

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and ~~1500 microfarads each, and eight capacitors 22 rated~~  
~~at 400 volts and 100 microfarads each. A rectifier~~  
~~circuit 23, limiting resistor 24 and flash trigger~~  
~~circuits 25 complete a power supply circuit for the~~  
5 ~~flash unit. The flash unit is arranged to selectively~~  
~~produce three levels of intensity of light, namely 400,~~  
~~800 and 1600 watt seconds.~~

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10 ~~a second cooling fan 27, and a cable 28 for delivering~~  
~~bit stream data signals from the analogue to digital~~  
~~connectors 15 to the PC.~~

The ~~scanner shown in the Figure 4~~ is typically about 400  
15 mm long, 150 mm wide and 400 mm high and weighs 6.72kg  
or 8.6kg (incl. Nikon D1 camera) and so is easily  
~~potable, portable.~~

As mentioned earlier, the data can be captured in less  
than 1/1500 second for each exposure in a normal room  
20 light environment with 100 to 150 lux illumination,  
~~say.~~ It is also not necessary for the subject to  
'pose' for extended periods of time in order for the to  
'pictures' to be taken.

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